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A study on the development of hydropower potential in Turkey

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ABSTRACT

In this study, the development of energy demand in Turkey, the utilization of hydropower potential as well as the problems related to the operation, construction and development phases of hydropower plants have been examined. The number of hydropower plants, their overall installed power (MW), their annual energy production capacity (GWh/yr) and their technical hydropower potential utilization rations have been calculated for the hydropower plants existing in the 25 hydrological basins located in Turkey. The total installed power for hydropower plants under operation for the basins examined in the year 2012 has been calculated as 16,926.80 MW. When the technical hydropower energy potential is taken into account, 28% of hydropower plants are under operation, 27% of them are under construction and 22.4% are under development. In all of the basins, if all of the 1776 projects which are under operation, construction and development are examined, then the total installed power will be 48,298.20 MW, and the annual hydropower production will be 167,333.30 GWh/yr. Hence, as a result, the 77.33% of the technical potential will be utilized. In addition, environmental effects of hydropower plants in the operation and construction phases have been researched.

Contents

1. Introduction

Rapid increase of population and industrialization in the 20th century has created a huge energy demand. According to United States Department of Energy [1], total world consumption of marketed energy is projected to increase by additional 57% from 2004 to 2030. Energy is considered to be a significant factor in economic development and the prime agent in generation of wealth. However, much of the world's energy is currently produced and consumed in ways that could not be sustained if technology were to remain constant and also if overall quantities were to increase substantially. Electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize the pivotal role of electricity in improving the living standards of people and for sustaining economic growth [2]. Global energy utilization has risen by 70% since 1971 [3] and is predicted to increase by 40% by 2030 [4] On the other hand, approximately 1.6 billion people have no access to electricity [5]. Fossil fuel-oriented energy sector has been accused of being the main source

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of global warming. Increased awareness of climate change and international agreements such as Kyoto Protocol have forced the governments to search for alternative energy sources; and increased oil prices have also accelerated this process. Within this conjuncture, governments have started to pay more attention to renewable energy technologies. Investors are encouraged to develop renewable energy technologies. Among these technologies, hydropower is the cheapest and the most widely used technology that is available. In 2007, 16% of the world's total electricity was generated in hydropower plants [6]. Hydropower is a renewable energy source based on the natural water cycle. Hydropower is the most mature, reliable and cost-effective renewable power generation technology available [7,8]. Hydropower schemes often have significant flexibility in their design and can be designed to meet base load demands with relatively high capacity factors, or have higher installed capacities and a lower capacity factor, but meet a much larger share of peak demand. In addition to grid flexibility and security services (spinning reserve), hydropower dams with large reservoir storage will be used to store energy over time to meet system peaks or demand decoupled from inflows. Storage can be over days, weeks, months, seasons or even years depending on the size of the reservoir.

Hydropower has been used for more than a century and it has become the major source of electricity for 55 countries [5]. Although it is widely used all around the world, only one-third of the economical hydropower potential has been utilized yet [9]. In Asia, Africa and South America, a great portion of the economical potential remains to be developed. On the other hand, the developed countries have already utilized much of their economical potential. However, these countries continue investing in renewable resources, especially small hydropower projects.

In this study, the development of energy demand in Turkey, the utilization of hydropower energy potential, environmental effects and the number of hydroelectric power plants that are under operation, construction and also under development, their installed power levels, their annual production levels, their technical hydropower potential calculations as well the problems related to their operation, their construction and also the development phase of hydroelectric power plants have been targeted.

2. Material and method

2.1. Material

Turkey is located between 26–45° eastern longitudes and 36–42° northern latitudes. Turkey is a country with a surface area of 780,000 km^2, namely 78 Mha and a population of 74,724,269 people. Located at the border between Europe and Asia it acts as a transit country for fossil fuels. Turkey has a mountainous landscape with an average elevation of 1132 m that is about three times higher than Europe's average. This topography favours the formation of high gradient mountain streams which are suitable locations for hydropower development. Turkey has a semi-arid climate with some extremities in temperature. Annual mean precipitation in Turkey is around 643 mm, which corresponds to 501 Bm^3 of annual water volume in the country. Total annual surface runoff amounts to a volume of 193 Bm^3 of water. Turkey has vast hydropower resources. Turkey is divided into 25 surface hydrological basins. Annual average flows of these basins amount to about 186 km^3. While basin yields vary, the Euphrates and Tigris basins account for 28.5% of the total potential of the country (Fig. 1). With 25 river basins and a varied topography, Turkey has 16% of Europe's theoretical hydropower potential and 1% of the world's total. Turkey has the second largest hydropower potential of all European countries, even though geographically the major part of Turkey is located on the Asian continent [10,11]. In this study, in order to determine hydroelectric energy potential in Turkey for 2012, data have been examined [12–15]. From these studies, it has been put forward that 2052 hydroelectric power plant projects have been developed in the 25 hydrological basins which have been in the scope of this study. 11 Projects recommended by the private sector have been refused in the project evaluation

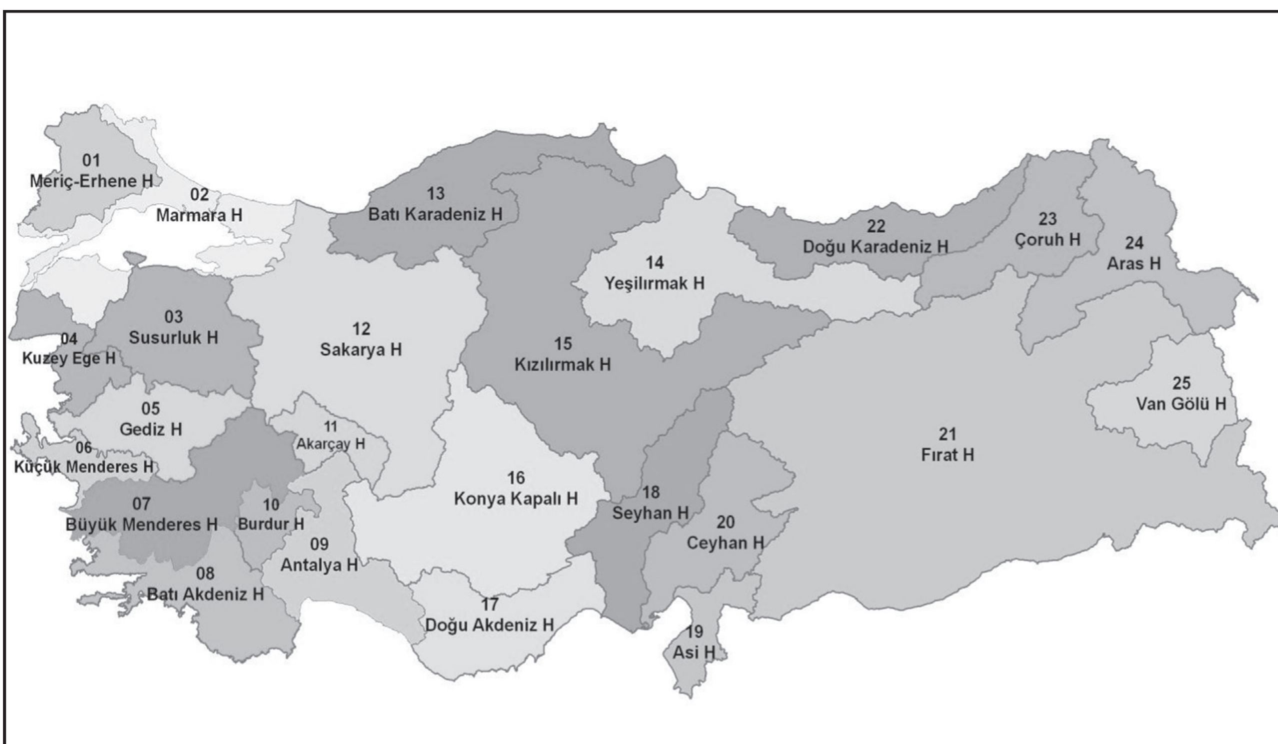

Fig. 1. Map of hydrological basins studied in Turkey.

phase; 2 projects have been taken out of operation; and 263 projects have not been able to move forward after their applications. As a result, 276 projects have been taken out of scope of this study and the evaluation has been conducted over the remaining 1776 projects.

2.2. Method

The total (gross) and technical hydropower potential has been calculated as per the surface flow amount which has taken place in 25 hydrological basins, Turkey. The 50% of the total hydroelectric energy amount is taken into account as technically usable energy, while 30% is taken as economically usable. "*The gross hydropower potential*" is identified as the theoretical average flow and fall values without taking into account the technical and economic feasibility of the production potential of current hydropower resources. The gross hydropower potential of Turkey is approximately 433 GWh/yr. Without the stipulation that it can be made economical, the case in which the total production amount that can be achieved by using all of the technical hydropower resources of the country is known as "*technical hydropower potential*". The technical hydropower potential of Turkey is around 216.5 GWh/yr. The part of the gross hydropower potential that can be utilized both technically and economically is known as "*technical and economical hydropower potential*". While it shows some differences year to year, currently, Turkey's technical and economical hydropower potential has been calculated to be 130 GWh/yr [10,16]. The socio-economical development of Turkey is dominated by a strong growth of population and simultaneously by a steady, remarkable increase of energy demand and consumption. These circumstances make the Turkish energy market critically sensitive to the global development of energy politics and prices. One way out of this critically vulnerable situation may be the utilization of all the remaining hydropower potential of Turkey. In order to accelerate the utilization of energy resources, including the huge potential of renewable hydropower, the energy market has been privatized and private investors are now allowed to own and operate hydropower plants, particularly of small and medium size. Singularly, also large hydropower plants are developed by private companies, such as both river-run and storage plants. In Turkey, the monopoly of the public sector on electricity generation was abolished in 1982 and the private sector was allowed to build power plants and sell their electricity to Turkish Electricity Administration. The first law setting up a framework for private participation in electricity industry was enacted in 1984 (Law no. 3096). This Law forms the legal basis for private participation through Build Operate and Transfer (BOT) contracts for new generation facilities. An additional law, namely the Build-Operate and Own (BOO) Law (no. 4283), for private sector participation in the construction and operation of new power plants was also enacted in 1997 again with guarantees provided by the Treasury [17]. In the study area, the number of hydroelectric plant projects which are under operation, construction and under development, as well as their established power (MW), annual energy production (GWh/yr) and technical energy potentials have been calculated for the basins which have been studied. Furthermore, the development of electrical energy demand in Turkey between the years 1972 and 2012, and the increase in demand for domestic, commercial and industrial users have been calculated using Excel and displayed in graphical form in this research study.

3. Discussion and results

3.1. The development of energy demand in Turkey

While the amount of electrical energy consumption per person in Turkey in 1923 was only 3.3 kWh/yr, in 2008 it reached the value of 2400 kWh (this value today is 2781 kWh). This value is quite below the energy consumption of world average, which is 2782 kWh and the average of developed countries at 9800 kWh [18]. When compared with other countries, the electrical consumption per person in Turkey is below the average of EU and OECD countries. The countries with the highest consumption of energy per head are Iceland, Norway, Kuwait, Qatar, Canada, Sweden and USA. Of these countries, since Norway, Sweden and USA have lower energy densities, their prosperity levels are higher [19]. While in Turkey, there has been only 0.80 GWh energy capacity present in the 1950s, this ratio has increased by 388 times to 310 GWh per year. In 2011 the total installed power capacity from all sources was 53.235 MW and best-case full production would be 310.570 GWh. However, consumer energy delivered was 229.395 GWh which included effects of economic recession, technical problems, drought, and distribution efficiency. The capacity utilization for energy production has been around 73.8%. The capacity utilization in thermal power plants has been 70.8% on average and around 84.5% with hydroelectric power plants. The total established power of Turkey in 2012 has increased by about 8% compared to the previous year and has reached 57.059 MW; however, electrical energy consumption has increased by 5% to become 239,470 GWh [20]. Electrical energy demand in the period 1970–2012 has been growing over 8% annually (Fig. 2). In order for the demand to meet the expectations, it is essential to increase the established power and reliable production by double. When the electrical consumption of developed countries is examined, it is foreseen that the present demand will reach a saturation level and that it will reduce to a ratio of 1–2%. In Turkey, it is predicted that the rise in the population will slow down in the near future and that it will start decreasing. Moreover, it is also predicted that the industrialization and urbanization process will continue to be an effective force from West to East. During the period of 1990–2009, when the subscriber consumption values per head are examined, it is seen that 2.09 times increase in domestic users has taken place (Fig. 3), along with 4.42 times increase in commercial users (Fig. 4) and 6.73 times increase with industrial users (Fig. 5). While there are some deviations in the latest data for the previous years due to the global recessions, it can still be seen that there is a general increase. The total energy consumption of Turkey in the year 2012 was 239,470 GWh and it has the ranking of 23rd highest electrical consumption in the world. The great portion of its energy consumption comes from coal and natural gas for which there is dependency to the outside world by Turkey. The 43.75% (104,148.5 GWh) of energy produced in Turkey is from domestic resources, while 56.52% (135,348.4 GWh) is from foreign resources. Of the total energy produced, about 43.64% comes from natural gas, 28.04% comes from coal, 24.16% is hydraulic, 2.45% is wind, 0.375% is geothermal and 1.34% is from other sources [21,22]. Arslan [23] stated that Turkey's hydroelectric potential can meet 33–46% of its electric energy demand in 2020 and this potential may easily and economically be developed. In between the years 1990 and 2012, Turkey's ability to handle energy consumption by energy production through domestic resources has decreased. While this percentage has been around 48.10% in 1990, it has become 43.90% in 2012 [21]. The total of renewable energy has been 64.62 GWh and this value is about 26.98% of the total production. The renewable electric power capacity of the world and the European Union is 1360 and 294 GWh, respectively [24].

3.2. The utilization of Hydraulic potential in Turkey

The surface flow amount of the 25 basins studied, as well as their total hydropower potential, technical hydropower potential, the number of hydroelectric power plants in operation, construction as well as under development, their total power and the

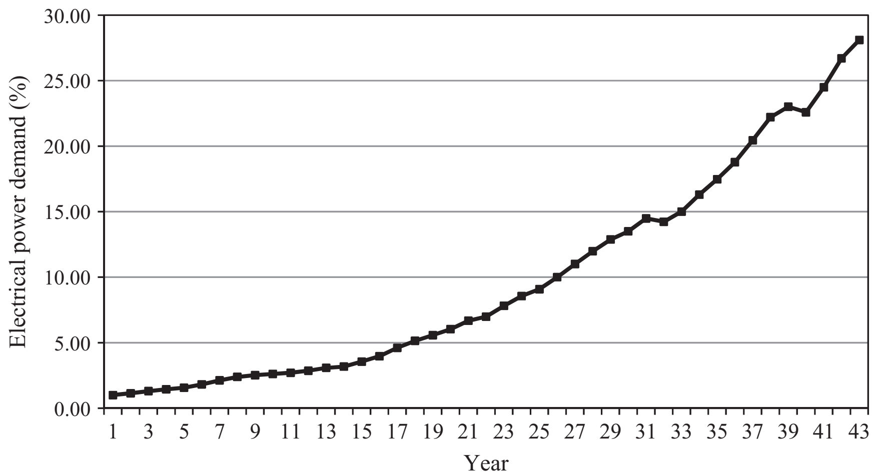

Fig. 2. The development of electricity demand in 1970–2012.

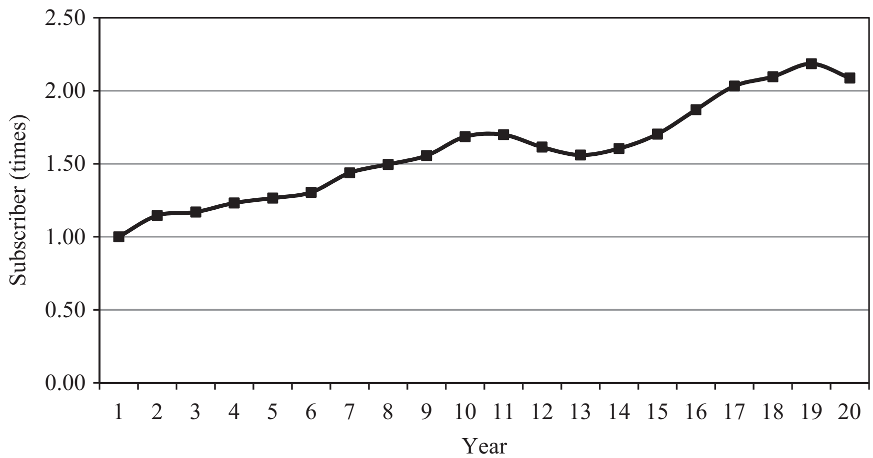

Fig. 3. Development of per subscriber demand in domestic subscriber in 1990–2009.

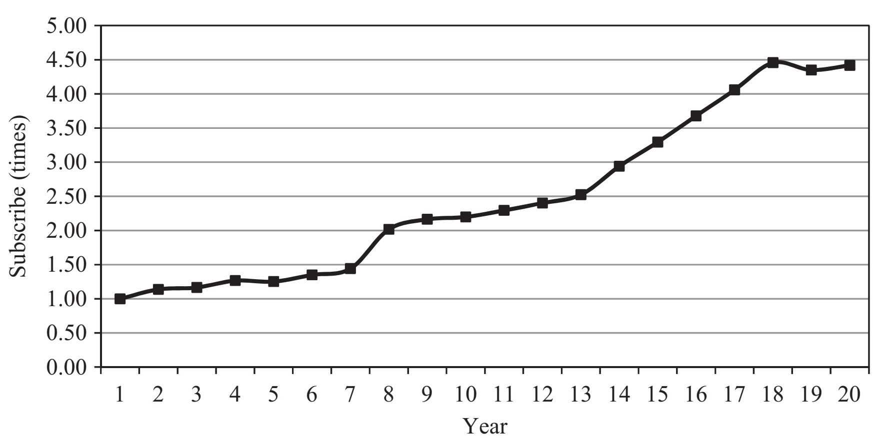

Fig. 4. Development of per subscriber demand in commercial subscribers in 1990–2009.

annual hydroelectric production have been calculated and they have been given in Table 1. A total of 1776 projects have been developed in these basins, and of these projects 281 of them (15.82%) are under operation, 557 of them (31.36%) are under construction and 938 of them (52.82%) are under development. The total power of the 1776 projects is 48,298.20 MW and the annual energy production is 167,333.30 GWh/yr. 1018 of these projects (57.31%) are being developed by the private sector. The total power of hydropower plants still under operation by 2012 is 16,926.8 MW. Moreover, the power of the hydroelectric plants where the construction is continuing is 16,933.30 MW and the ones under development has a capacity of 14,438.10 MW. Since natural gas has been given more importance in electrical energy production lately, as it can be seen in Fig. 6, hydroelectric energy production has decreased rapidly along with its ratio in total energy production. While hydroelectric energy ratio was 30.60% in 2004, it has decreased to 25.3% in the year 2012. When comparing other countries with Turkey, Norway's energy generation comes to

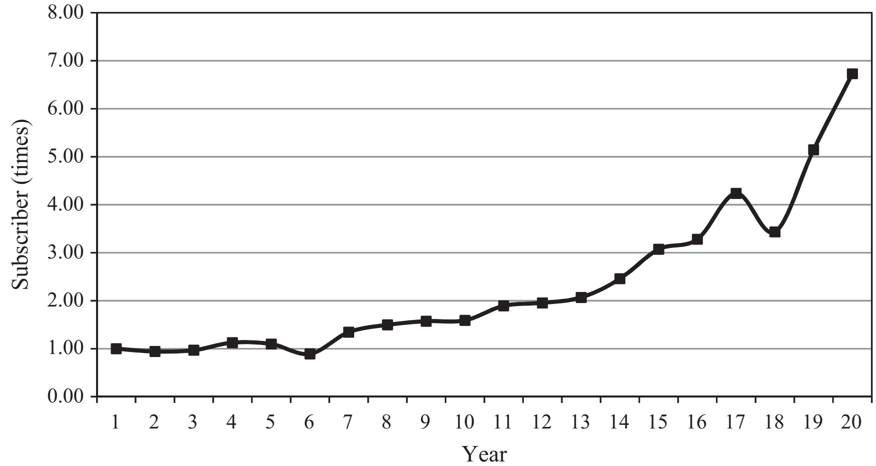

Fig. 5. Development of per subscriber demand in industry subscribers in 1990–2009.

almost 100% hydropower, with hydropower accounting for 97% of generation in 2009 and 99% in 2010. In 2010, hydropower accounted for 84% of the total generation in Brazil and 74% in Venezuela. Central and South America generate nearly 64% of all their energy from hydropower [25]. There are a number of countries in Africa that produce close to 100% of their grid-based energy from hydropower. Russia has an estimated 50–55 GW of installed hydropower capacity, which represents about 51% of the country's total energy capacity [26].

The total established power for the existing 281 HPP projects operated at basins would be 16,926.80 MW and the annual energy production value has been calculated as 60,605.70 GWh/yr. Technical hydropower potential ratio of HPP under operation has been realized as 28%. This value is expected to reach 33% in the future. This ratio is around 86% in USA, 78% in Japan, 68% in Norway, 56% in Canada and 57% on average in EU countries [24]. The distribution of technical potential utilization ratios as per the examined basins for projects under operation has been given in Fig. 7. In the basins which have been studied, the technical potential utilization ratio of HPP changes from 0% to 44.85%. The ratios of HPP which are under operation in Fırat-Dicle, Ceyhan, Kızılırmak and Yeşilırmak basin are greater than others. Fırat-Dicle with its 127,304 km^2 drainage area and elevation range between 500 and 5000 m, itself responsible for 30% of the country's hydropower potential. Turkey's biggest hydro-power plants were constructed on the Fırat River namely: Ataturk (2400 MW), Karakaya (1800 MW) and Keban (1330 MW). Moreover, the Karadeniz region, which has steep and rocky mountains that extend along the coastline, has a considerable hydropower potential. East Black Sea and Çoruh basins are of particular importance in terms of hydropower potential. The changes in the installed power per year for the operational HPP in Turkey have been given in Fig. 8. While the installed power of HPP under operation for the year 2000 was 11,175.2 MW, it increased to 16,926.80 MW in the year 2012. The hydroelectric energy established power has shown an increase over the years. In the 1970s, it was 725 MW, in 2005 12,906 MW and it was 15,831.20 MW in 2010. Of the 281 hydroelectric power plants in Turkey under operation, 13,318.9 MW (79%) of them are of dam-type power plants and 3607.9 MW (21%) are river-run type power plants for the years 2002–2012 (Fig. 9).

The established power of 557 HPP projects which are in construction phase is 16,933.30 MW and the annual energy production has been calculated as 58,066 GWh/yr. The technical hydropower potential of HPP under construction is 27%. When we examine the construction process of 557 projects in July 2012, we find that 396 projects with 9930.3 MW/34,912.5 GWh/yr capacity are in construction phase with 0–50%, 111 projects with 4039.2 MW/13,278 GWh/yr capacity are at 50–99% and 50 projects with 2963.8 MW/9863.8 GWh/yr capacity is vague as to the level of construction. With these 50 projects, where there is ambiguity in their level of construction, there are also 17 different legal problems. When taking into consideration other countries, China added 16 GW during 2010 to reach an estimated 210 GW of total hydropower capacity. Brazil brought around 5 GW on stream in 2010, bringing its existing capacity to 81 GW while a further 8.9 GW is under construction [27,28]. In Western Asia, there is a total of 15.5 GW of capacity under construction, with India accounting for 13.9 GW and Bhutan for 1.2 GW [28]. Canada added 500 MW of capacity in 2010, raising the total installed hydropower capacity to 76 GW. However, the future should see higher rates of capacity coming on stream as more than 11 GW of new projects were under construction in Canada by early 2011. An estimated 1.3 GW of this is due to become operational before the end of 2012 [27,24] (IHA, 2011 and REN 21, 2011). Canada has a total of 21.6 GWh of hydropower capacity at different stages of construction [28]. Turkey, like other countries in the world, makes an effort to increase its energy production with emphasis on hydropower plant construction. The distributions of technical potential utilization of those projects under construction are given in Fig. 10. In the examined basins, the ratio of HPP under construction to technical potential changes between 0% and 68.82%. In the Çoruh, Seyhan, Eastern Black Sea, Aras and Fırat-Dicle basins, the ratio of HPP under construction is higher than other basins. When the 50–99% projects are taken into account, it can be seen that in the near future with the additional use of 5% of technical potential, the ratio of HPP under operation can rise up to 33%. Since majority of the HPP under construction is made by the private sector, the way in which the investment is made and amount of investment affect the way the construction progresses.

The projects which are under development include HPP projects that are under planning stage, as well as on water utilization agreement, bidding and on licensing phase and on undefined phase. It has been seen that the established power of 938 projects at the examined basins is 14,438.10 MW and the annual energy production capacity is 48,661.60 GWh/yr. The percentage of the projects under development to technical hydropower potential has been calculated as 22.33%. When the status of the 938 projects under development is examined in July 2012, it is seen that 63 projects with 993.6 MW/3475.8 GWh/yr capacity is at “Ambiguous”, 17 projects with 793.7 MW/2356.9 GWh/yr capacity is at “Bidding”, 382 projects with 5814.3 MW/19,802.96 GWh/yr capacity is at “Licensing”, 300 projects with 4391 MW/15,065.9 GWh/yr is at “water utilization agreement”

Table 1
Hydropower energy potential of basins in Turkey.

Basin Number	Basin name	Runoff (billion m3)	Gross Energy (GWh/yr)	Technical Potential (GWh/yr)	Plants in operation stage			Plants in construction phase			Plants in under-developed phase			Total Power Plans		
					Number	Power (MW)	Yield (GWh/yr)	Number	Power (MW)	Yield (GWh/yr)	Number	Power (MW)	Yield (GWh/yr)	Number	Power (MW)	Yield (GWh/yr)
1	MERİÇ	1.33	1000	500	0.00	0.00	0,00	0.00	0.00	0.00	4.00	23.90	68.00	4.00	23.90	68.00
2	MARMARA	8.33	5176	2588	2.00	10.90	50.00	1.00	1.80	6.10	7.00	15.30	69.40	10.00	28.00	125.50
3	SUSURLUK	5.43	10,572	5286	6.00	128.70	442.30	7.00	178.90	539.80	28.00	296.50	934.70	41.00	604.10	1916.80
4	KUZEY EGE	2.09	2882	1441	0.00	0.00	0.00	0.00	0.00	0.00	12.00	16.10	69.90	12.00	16.10	69.90
5	GEDİZ	1.95	3916	1958	1.00	69.00	192.00	0.00	0.00	0.00	12.00	72.50	188.60	13.00	141.50	380.60
6	KÜÇÜK MENDERES	1.19	1374	687	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	BÜYÜK MENDERES	3.03	6262	3.131	11.00	191.70	589.60	7.00	78.80	267.50	13.00	127.60	414.30	31.00	398.10	1271.40
8	BATI AKDENİZ	8.93	13,596	6.798	12.00	211.00	901.70	18.00	330.70	1103.80	28.00	293.00	1099.40	58.00	834.70	3104.90
9	ORTA AKDENİZ	11.06	23,080	11,540	12.00	811.60	2842.80	30.00	416.30	1420.80	45.00	712.20	2636.90	87.00	1940.10	6900.50
10	BURDUR	0.5	884	442	0.00	0.00	0.00	1.00	2.00	5.20	0.00	0.00	0.00	1.00	2.00	5.20
11	AFYON	0.49	542	271	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.40	11.60	3.00	2.40	11.60
12	SAKARYA	6.4	11,334	5667	10.00	510.60	1118.00	16.00	227.10	775.00	31.00	516.80	1295.80	57.00	1254.50	3188.80
13	BATI KARADENİZ	9.93	17,914	8957	10.00	112.90	488.00	34.00	488.90	1676.60	65.00	622.90	2057.60	109.00	1224.70	4222.20
14	YEŞİLIRMAK	5.8	18,684	9342	20.00	1061.70	3866.90	33.00	666.90	2584.40	34.00	221.60	769.70	87.00	1950.20	7221.00
15	KIZILIRMAK	6.48	19,552	9776	16.00	1433.10	4131.40	17.00	749.40	2753.20	23.00	220.70	823.00	56.00	2403.20	7707.60
16	KONYA	6.48	1218	609	3.00	1.80	5.40	1.00	17.00	59.50	5.00	44.80	147.90	9.00	63.60	212.80
17	DOĞU AKDENİZ	11.07	27,444	13,722	23.00	571.10	2274.40	15.00	560.30	1847.60	37.00	860.30	2854.20	75.00	1991.70	6.976.20
18	SEYHAN	8.01	20,874	10,437	14.00	850.60	3225.60	22.00	1269.40	4744.90	24.00	292.90	1054.30	60.00	2412.90	9024.80
19	ASİ	1.17	4896	2448	1.00	0.30	1.00	4.00	37.30	129.30	13.00	95.70	316.10	18.00	133.30	446.40
20	CEYHAN	7.18	22,162	11,081	28.00	1478.10	4871.50	25.00	562.10	1469.10	36.00	299.80	1036.10	89.00	2340.00	7376.70
21	FIRAT-DİCLE	52.94	132,828	66,414	56.00	7806.90	29,787.50	98.00	5533.60	19,204.20	174.00	4922.80	16,981.10	328.00	18,263.30	65,972.80
22	DOĞU KARADENİZ	14.9	48,478	24,239	28.00	988.00	3420.90	150.00	2737.70	9553.00	199.00	2516.80	8563.20	377.00	6242.50	21,537.10
23	ÇORUH	6.3	22,600	11,300	13.00	585.20	2049.20	52.00	2468.20	7777.30	96.00	1561.50	5190.90	161.00	4614.90	15,017.40
24	ARAS	4.63	13,114	6557	7.00	67.80	226.20	23.00	556.60	1968.80	32.00	643.50	1870.80	62.00	1267.90	4065.80
25	VAN KAPALI	2.39	2592	1296	8.00	35.80	121.30	3.00	50.50	180.20	17.00	58.90	208.60	28.00	145.20	510.10
	Turkey in general	186.06	433,000	216,500	281.00	16,926.80	60,605.70	557.00	16,933.30	58,066.00	938.00	14,438.10	48,661.60	1776.00	48,298.20	167,333.30

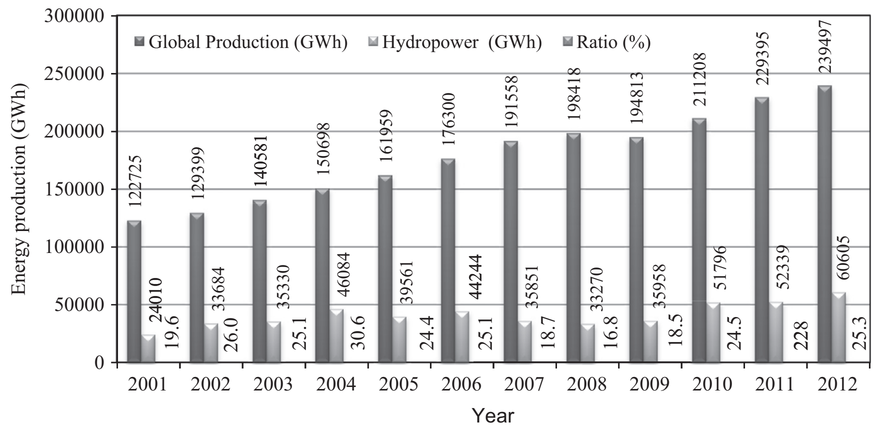

Fig. 6. Amount of hydraulic power generation in total energy production in Turkey.

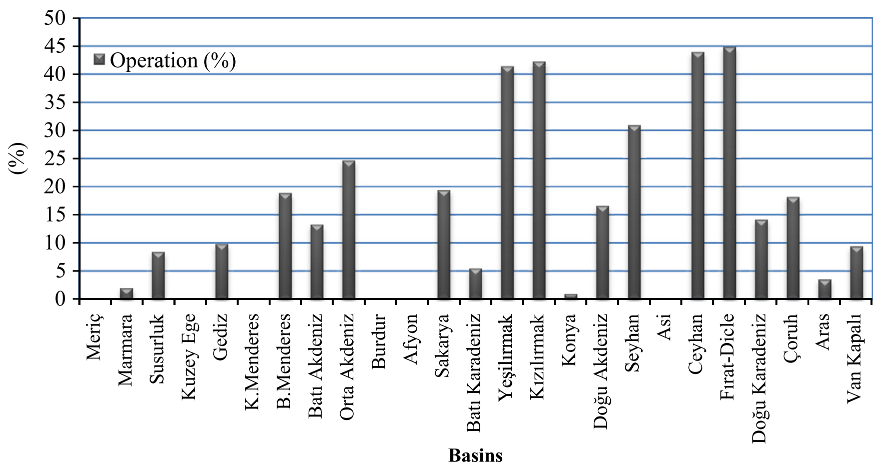

Fig. 7. Ratio of HPP operated in the basins researched.

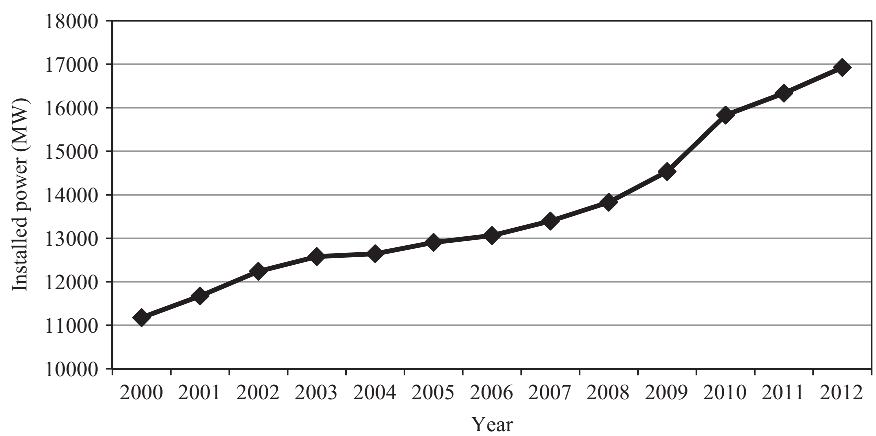

Fig. 8. Development of installed power of HPP in Turkey.

and 176 projects with 2445 MW/7360.1 GWh/yr capacity is at "Planning" stage. In South America as a whole, 11 GW is planned and a further 16.3 GW is at the feasibility stage [28]. In Fig. 11, technical potential utilization ratio as per developing projects per basin is given. The developing projects as per basin distribution change around 0–45.93%. The project ratios at Çoruh, Eastern Black Sea, Fırat-Dicle, West Mediterranean and Sakarya are greater than other basins. Majority of the projects under development are in the licensing, water utilization agreement and at planning stage.

3.3. *The problems of HPP in Turkey*

If we are to discuss the problems related to hydroelectric power plant projects, one of the most important problems from the investor point of view is the high initial investment cost. In addition to this, especially hydroelectric power plants with reservoirs harbour some social and environmental effects. While renewable energy projects are known as "*green energy*", there are some negative effects of the projects on the environment. Since it cannot be stated that there is an energy production

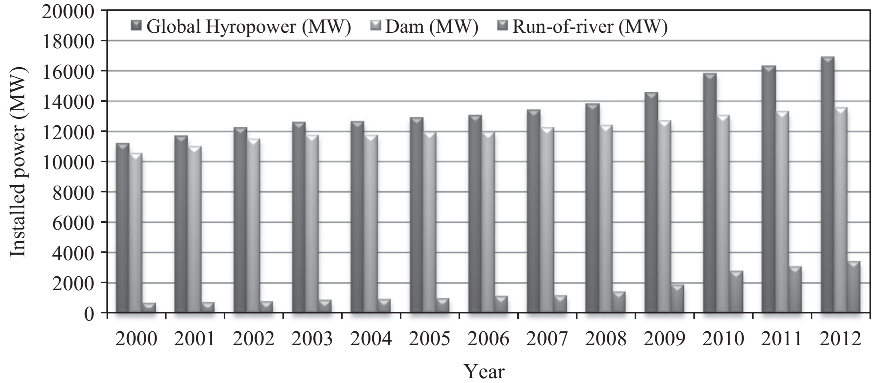

Fig. 9. Development of installed power of HPP constructed on dam, run-of-river, and global hydropower.

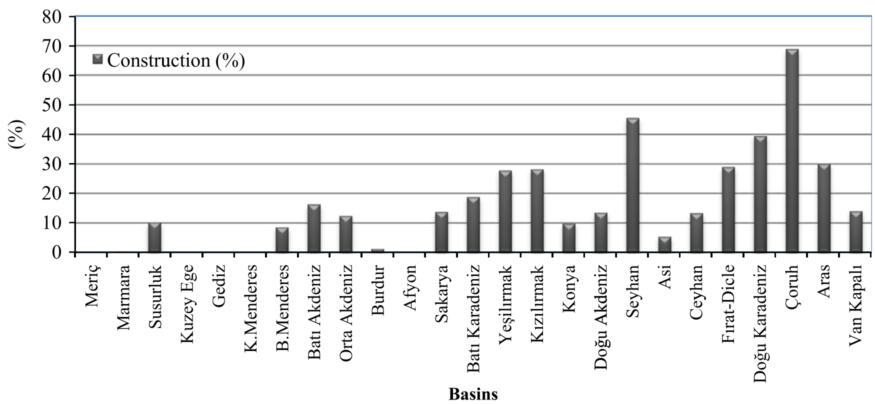

Fig. 10. Ratio of HPP being constructed in the basins researched.

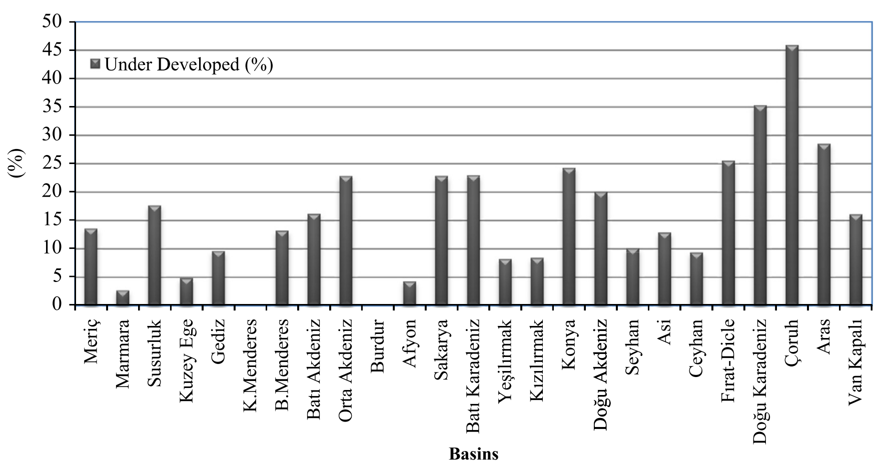

Fig. 11. Ratio of HPP under development in the basins researched.

method which does not affect the environment, likewise it cannot be stated that hydroelectric power plants do not affect the environment. However, these effects are very small and at negligible levels as compared to fossil energy resources.

Compared to reservoir-type hydroelectric power plants, the river-run-type hydropower plants have lesser negative effect on the ecological balance and on the social environment. However, various power plants which are in project, establishment or in operation phase in the country are always on agenda due to concern on possible potential damages on the natural and social environment as well as about the possible damage that can arise in the future.

There are certain arguments and even confrontations that take place between the company which is constructing the power plant and the local public living near the construction. These confrontations take place and sometimes even the security forces are forced to intervene. The matter goes to the courts and the investment stops during the legal litigation. In Solakli valley in the Black sea region, Turkey, there was a semi-violent case where affected villagers and company workers struggled in the hydropower sites to claim their rights. Police and gendarme evacuated and even arrested villagers on the grounds of intrusion [29]. In Yuvarlakcay HPP construction, many local community members show their concerns to this changing ownership patterns by saying that: "*the state sold us for 49 years*"; "*we don't need energy, it is our duty to protect this river for the future of our children*"; "*this is utterly a theft, water belongs here*" [30–32]. Without doubt, this situation is caused by the fact that the support of the local public for the

HPP has not been obtained and also because of the fact that the process has been wrongfully managed from public relations point of view.

According to the law in effect, any corporal entity (Company/Organization) that wishes to get an electricity production license must submit the “Environmental Impact Assessment” report of “*Not Required*” or “*Affirmative*” decision to the Energy Markets Distribution Organization (EPDK) as required by the Environmental Impact Assessment (EIA) regulations. The 6th clause of the EIA regulations which forms the managerial structure, technical procedures and principles for the EIA process state that “For projects that are relevant to these regulations; investment cannot be started and no support, approval, permission, construction nor operation license will be granted unless “Environmental Impact Assessment” is “*Affirmative*” or “*Not Required*” decision is given by the approving body”.

Observation and inspection is an important stage to break the misconception against HPP. When observation and inspection is not done properly in these hydropower plants, it causes the complete loss of flora, as well as the destruction/disintegration of habitats in large areas. Moreover, the damage to the water system of the area happens due to the filling of the stream bed, since excavation is not properly stored and as a result it is just poured down the slopes.

In order for the process to be trustworthy, it is essential to prepare Cumulative Effect Evaluation (CEE) reports which explain the correlation between the whole basin and the multiple structure systems based on the basin, rather than the EIA reports. This will create more safe, encompassing and stable results to be put forward. There are lots of controversial practices which are related to the scope, the preparation as well as to the checking of EIA reports. However, in developed countries, there is a lot of serious work and rigor during the preparation of EIA and the other feasibility reports. Scheumann et al. [33] also argue that the EIA is not an instrument to assess the cumulative effects and impacts of multiple projects on a single river. Instead she suggests that Turkey align itself with the EU directive on Strategic Environmental Assessment (SEA). Accordingly, the SEA is considered as a better instrument to assess the additive, cumulative and synergistic effects of policies.

Especially in Eastern Black Sea region, one of the factors that were determined was the fact that many of the fish species identification studies in the EIA reports were conducted only as a literature survey without any field work and that the studies were not even conducted on site. In fact, in some EIA reports, even there was no information about the type of fish species and about the fish migrations in the area situated near the hydropower plant.

One of the most important contributions that EIA has to a HPP project is that it takes into account the views and the worries of the public by having their participation in the process as well. Since necessary importance is not given to this process in EIA, which is also known as the public participation meeting, this can cause issues such as people not knowing about expropriation of their lands until after the project starts. Hence, as a result, many legal disagreements cannot be handled beforehand, thus causing the problems to be turned over to the courts. Due to this reason, it is essential for the investors to ensure the participation of the involved parties, which are likely to get affected from this project to come to this meeting.

One of the biggest effects of the river-run-type hydroelectric power plants on the environment is on the aquatic ecosystem. During the establishment stage and after the establishment of the hydropower plant, in order to make sure that any effects on the aquatic environment do not cause the destruction of aquatic life, the necessary procedures for protection have been stated in the Official Gazette dated 26.06.2003 with no 25150, on regulations related to principles and procedures on Signing Water Usage Rights Agreement for Production Activity In The Electric Market. It states in the 4th clause that “The Company/Organization will permit enough water to be led back to the river bed which is sufficient to ensure continuity of natural life in the downstream of the river bed and the HPP will also have to release enough water to suffice water rights in the region. The amount and the timing of the water that is to be released into river bed has to be in the EIA report approved by the Environment and Urban Ministry. This report is to be prepared by the corresponding company related to the hydroelectric power plant and it will be defined in the Project presentation file. However, the amount of water that is to be released downstream in order to ensure the continuity of natural life will have to be *at least 10% of the average water current in the last 10 years*. When the ecological needs are taken into consideration in the EIA report, and if it is also seen that this average amount may not be sufficient to sustain ecological criteria; *then the amount of water released will be increased*”. The amount of water that is needed for an aqua life, along with enough ecological water sources to ensure continuity of the ecosystems as well as the conditions of releasing water, should be determined with a scientific method. The Tennant (Montana) method, which is used more extensively than other methods with a rate of 30% utilization worldwide [34], is also the most widely used method in Turkey. It is stated that the Tennant Method should be used in rivers with a slope of less than 1% [35] and there should be differences concerning the use in every area or country [36,37]. This value in Austria is the value between annual minimum flow and the annual maximum flow, in Greece it is 1/3 of the mean summer flow, and in England no standard method exists; as a result, the criteria are set by carrying out experimental work in field conditions before the license is given [38]; in Germany this is between 1/3 and 1/6 of the mean minimum flow, in France it is generally more than 1/10 of inter-annual mean flow, and more than 1/20 of inter-annual mean flow in high flow rivers larger than 80 m^3/s [39]. In the beginning of the 2000s, the environmental flow was 1% of mean annual flow in Turkey; it later increased to 2.5% and then to 5%, and at present it is situated at 10%. However, such a standard level of a minimum in-stream (or, environmental) flow is problematic, since it neglects the diverse nature of rivers. According to the experts in Turkey, 40–60% of water is needed for sustaining the ecosystems of rivers [40,18].

Many criteria have been arranged with the Water Usage Rights Agreement and environmental effects; in addition, the rights of other water users have been preserved. It has been made mandatory for the institution to place necessary observation equipment near the downstream in order to make sure that the amount of water that is to be released in the downstream is in fact released. During the acceptance stage of facility development, it is essential to check for the setup and the presence of the remote sensing observation equipment in order to make sure that they conform to the regulations.

The arguments related to environmental effects of HPP depend more on prejudices and initial preconceptions rather than on scientific research. In problems related to singular events, they are usually generalized toward all HPP projects. Also some criticisms are due to emotional reaction of the public. New technologies utilized during HPP construction have demonstrated that the environmental effects can be minimized with a proper setup and with proper compliance to regulations.

4. Conclusion and recommendations

To increase the energy production in Turkey and thus to decrease its dependence on foreign energy supplies, attempts

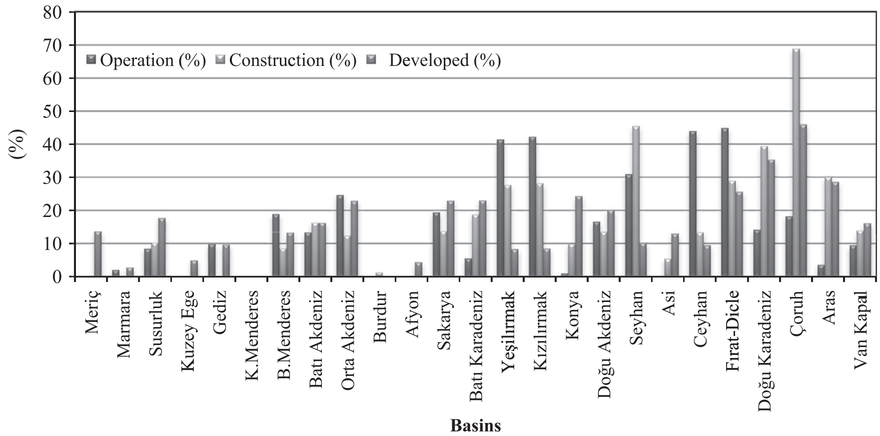

Fig. 12. Ratio of HPP being operated, constructed and developed in the basins researched.

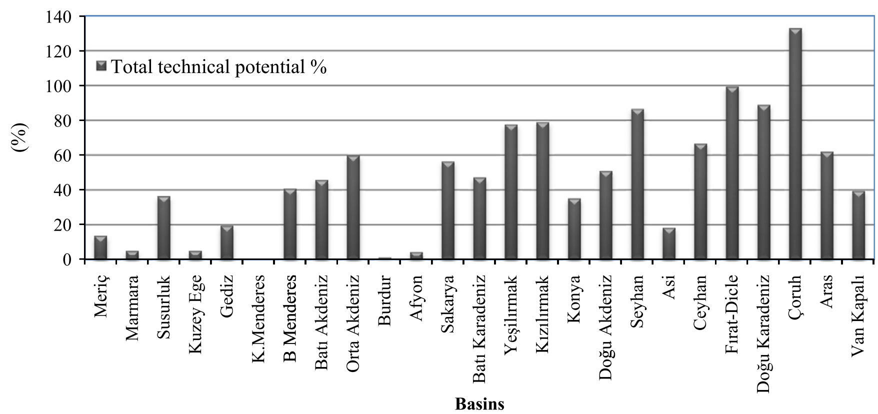

Fig. 13. Total technical potential utilization ratio of HPP under operation, construction, and development in the basins.

have been made by the governments to enhance the utilization of current sources and to promote the utilization of renewable energy resources. Among these renewable energy sources of Turkey, hydropower is regarded as one of the most stable and economical clean energy sources in the renewable energy alternatives which are present in Turkey.

The energy balance and the development in the electric demand have increased the importance of HPP projects. With the widespread use of HPP investments, some concerns on water sharing and environmental effects have surfaced. In order for these investments to be added to the economy, these concerns have to be resolved and the value as well as the importance of the projects has to be explained. Hence, an effort has been made to determine the utilization of technical hydropower potential for the projects developed in Turkey. For the basins related to HPP projects under operation, construction and development, the technical hydropower potential utilization ratios are shown in Fig. 12, while the total technical hydropower potential for operation, construction and development of hydropower plants is given in Fig. 13. When we examine the total technical potential utilization ratios, it is seen that it is quite high in the Çoruh, East Black Sea, Fırat-Dicle, Kızılırmak, Yeşilırmak, and Middle Black Sea basins. The reason for this stems from the fact that while the water resource shows large differences compared to other basins, the present topographical conditions allow the same amount of water to be used for different energy production. 98.9% of hydropower plants under operation and construction are found in 14 basins. The HPP projects under development is distributed to 23 basins. In the year 2012, the hydropower plants in operation have an installed capacity of 16,926 MW with an annual average generation of 60,605 GWh. Finally, when all projects are examined, the total installed capacity of hydropower will be nearly 48,300 MW with an annual hydropower production of 167,333 GWh. The technical potential of HPP projects under operation, construction and development to the total hydropower potential is 77.33%.

The energy consumption in Turkey in parallel with the rest of the world has increased with import due to low fossil resources and the dependency ratio to foreign resources being 56.52% in year 2012 for primary energy production. The most widely used foreign resource in energy production is natural gas. In the last 10 years, due to the national decision to use natural gas, the energy ratio of hydropower has been lowered down to 24.16%.

According to technical hydroelectric potential, 156 GWh/yr of hydroelectric energy gets dumped to the sea, since the required power plants are not constructed. Due to this, the loss per year amounts to around 11×10^9 US$. The 72% of the unused hydropower potential of 216.5 GWh/yr that the country possesses must be used and won into the national economy with the help of the private sector by processing 150 GWh/yr of energy.

Some of the factors which impede attaining potential power of HPP's in Turkey are lack of financing needed for construction, resist and pressure of the people living near HPP construction area, number of HPP's constructed in the basins, and amount of water released downstream for ecology.

As for the scenario that predicts a 6.3% increase in the annual energy demand, it is expected that consumption will increase by 11,000 GWh per year. This amount means that 3500 MW of installed power is to be added to the system every year. In order to achieve this, there is a need for a 3.5×10^9 US$ of investment.

In order for this amount to not be deducted from the budget, it is essential to give the necessary support in parallel to private sector investments.

Since the energy sector has entered a fast liberalization phase, as soon as projects have been announced, private sector applications have been accepted in a short period of time. There are criticisms, which state that the proper basin studies have not taken place and that sufficient technical analysis and evaluation have not been completed due to timing limitations put forward by the regulations. Due to the fact that the feasibility studies are generally carried out with water measurements, the fact of whether they are actually efficient projects is only seen after the revised work is completed after the licensing. Any changes completed in feasibility after licensing actually delay the construction process of the facilities [41].

European Union community supports the development of renewable energy resources. Due to this, in concordance with our production policy based on domestic resources, almost all of the total hydropower potential that we possess due to public and private investments must be made operational by 2030.

As in utilization of other renewable energy sources, hydropower plants also have effects on the natural environment. Primarily, they prevent the connection between upstream and downstream of the facility. Therefore, it has deteriorative consequences such as blockage of fish passages and protection, and interruption of sediment transport. To solve these problems, effective fish passages for local and migrating fish species should be provided in these environments.

Since basin planning does not take place during HPP investments as well as during the licensing process, EIAs are done singularly at point-to-point basis per project. However, it is essential to demonstrate the cumulative effects of projects planned at different arms of the water streams or on the same stream within the stream basin. In this context, first of all, it is essential to identify the sectors related to water in the basin. Then the natural resources, habitat and biological diversity of the basins should be defined and later electric production planning must be conducted without endangering the service and the health of the river ecosystem in the basin. As a result, EIA reports should be evaluated within this purview.

Studies should be started to remove, reduce or to compensate the effects of construction and operation HPP of river ecosystems by identifying methods used all over the world. A national HPP guidebook should be prepared and the necessary actions for its deployment must be identified. Mechanisms should also be formed and deployed for checking the EIA, construction as well as the operation process in an independent and objective way.

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